On the Spectra of the Alkaline Earth Fluorides and their Relation to each other.

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(Communicated by Prof. A. Fowler, F.R.S. Received April 21, 1921.)

[PLATE 6.]

1. *Introductory.*

It is well known that the limits of the series and the separation of doublets and triplets, which occur in the line spectra of chemically related elements, are intimately connected with the atomic weights of the elements involved. It seemed reasonable to suppose that numerical relations might also exist in the case of band spectra, and the present paper gives an account of an investigation undertaken to determine possible relations among the band spectra of similar compounds of different elements. Previous work by other observers suggested the fluorides of the alkaline earth metals as a suitable group of compounds for the purpose in view. In the first instance a more complete survey of the spectra of these compounds was made, and several bands in addition to those previously described have been observed. These new bands have proved of considerable service in the identification of corresponding bands in the different spectra, and details relating to them are accordingly included in the paper.

The beautiful bands of CaF_2, SrF_2, and BaF_2 were first observed in the flame spectra by Mitscherlich[*] as far back as 1862, but no systematic measurements were made until 1905, when observations of the bands of these compounds in the visible region were made by Fabry[†] with a spectroscope of not very large dispersion. Measurements of the same spectra from photographic plates were first made by Rosch[‡] and further measures were subsequently made by Leopold[§] in the case of SrF_2, and by George[||] in the case of BaF_2.

The ultra-violet bands of these compounds were studied by Olmsted[¶] in 1906, but the bands of the fluorides were not completely separated from those of the oxides, which in this region are closely grouped with those of the fluorides, particularly in calcium and strontium.

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[*] A. Mitscherlich, 'Pogg. Ann.,' vol. 121, pp. 459–488 (1864).

[†] Ch. Fabry, 'Astrophys. Journal,' vol. 21, p. 356 (1905).

[‡] J. Rosch, 'Z. Wiss. Photgr.,' vol. 4, p. 384 (1906).

[§] P. Leopold, 'Z. Wiss. Photgr.,' vol. 11, pp. 105, 137 (1913).

[||] H. George, 'Z. Wiss. Photgr.,' vol. 12, p. 237 (1913).

[¶] C. M. Olmsted, 'Z. Wiss. Photgr.,' vol. 4, p. 354 (1906).

The first attempt to discover a relation between the spectra of nearly related compounds was also made by Mitscherlich, who stated in a most general way that the greater the atomic weight the more towards the red the spectrum lies. Later, in 1874, Lecoq* suggested an equation of the type $x = n(1+q)^2$ connecting the bands of $BaCl_2$, $BaBr_2$, and BaI_2, where x = increase of λ between the spectra of the second and third compounds, n = increase of λ between the homologous spectra of the first and second compounds, and $q = B-A/A$, where A = increase of molecular weight from first to second compound, and B that from second to third. In 1894 Hartley,† experimenting on the banded flame spectra of metals, remarked that with an increase in atomic weight the heads of the bands come closer together. In the case of $CaCl_2$, $CaBr_2$, CaI_2, and $SrCl_2$, $SrBr_2$, SrI_2, Olmsted suggested the formula $\sqrt{(\Delta\lambda)}/\text{molecular weight} = \text{constant}$, where $\Delta\lambda$ is the mean of the differences in the wave-lengths of the first two or three consecutive heads of homologous series in the respective spectra.

Neither the formula of Lecoq nor that of Olmsted is applicable to the spectra of the fluorides under consideration. The new observations, however, have suggested a formula which appears to represent the facts very closely.

2. *Experimental Procedure.*

Observations were chiefly made with the concave grating in the Spectroscopic Laboratory of the Imperial College. The grating has 15,000 lines to an inch over 4 in. ruled surface and is of radius 10 ft. The dispersion obtained on the photographic plate is about 5·5 A. per millimetre in the first order. The negatives for measurements were mostly prepared in the second order, while those for reproduction were taken in the first order and subsequently enlarged.

The band spectra were conveniently produced in the electric arc between carbon poles fed with the various compounds and maintained by an electric main of 110 volts. The arc was extended to a flame by suitable admixture of sodium carbonate with the compounds used, so that the carbon poles could be drawn apart, giving a "flame" having a low order of temperature such as is required for the development of the bands. By carefully moving the arc to and fro, so as to keep only the coloured edge of its image upon the slit, the bands were seen practically free from the line spectrum of the metals, though numerous lines appeared at the centre of the arc. The admixture of sodium carbonate does not inconveniently complicate the spectrum and is a far more convenient method of maintaining a steady flame arc than that of broadening the arc into a wing shape with the help of a magnet, as was adopted by Eagle* in his experiments on hydrides.

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* Lecoq de Boisbaudran, 'Spectres Lumineux,' Paris, 1874.

† W. N. Hartley, 'Trans. Roy. Dublin Soc.,' vol. 7, p. 339 (1901).

Where the bands of the fluorides were free from admixture with those of oxides, they were photographed with the usual iron comparison, and their wave-lengths measured with reference to the iron lines, using Burns's wave-lengths as standards.

Where fluoride and oxide bands were superposed, the fluoride bands were sorted out in the following manner. Three comparison photographs were taken: 1. The fluoride and the oxide. 2. The fluoride and the nitrate. 3. The oxide and the nitrate. From the third plate the common bands and diffuse lines were marked out. These were evidently the bands of the oxides, or the faint diffuse lines of the metal itself. The third plate was taken to make sure of the elimination of the oxide bands, for often it was found that, when carbon poles were used, the oxides gave the more sensitive heads of the fluoride spectra in addition to their own spectra. From each of the first and second plates the common heads were left out, and the others were measured with reference to sharp metallic lines in the comparison oxide spectrum. The common heads omitted are believed to be those due to the oxides, for they were all identified with the common bands of plate 3. The wave-length of the sharp metallic lines—which were taken as reference lines in the measurement of fluoride bands from plates 1 and 2—were then accurately determined from another photograph of the oxides with the iron comparison. Several such plates were taken, and the results of the independent measurements of the wave-lengths of the fluoride bands were in close agreement. The results published here show the mean.

Before proceeding to describe the spectrum of any particular compound, it is best to define the terminology accepted in this paper; and this is more necessary, in view of the fact that, in certain instances, the terminology of band spectra not being completely fixed, misunderstandings arise between different observers.

A *band* is composed in general of a large number of lines, regularly distributed in the spectrum, starting from a line which is the most brilliant of the set, and which is called the *head* of the band. Ordinarily, a band does not occur alone; there are several, of similar character, which usually encroach upon one another, the whole forming a *series* of bands, which can be numerically expressed by certain well-known equations. The manner in which the successive heads occur in a series defines its *structure*. Generally, the different series of similar structure overlap with one another, forming a *group*, but sometimes they are well separated from one another; the different series then form different groups. The series is said to fall off toward the red or toward the violet, according to the direction in which the heads composing the series extend outward from the first head.

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* Eagle, 'Astrophys. Journal,' vol. 30, p. 231 (1909).

Proceeding toward the red, the various series have been designated by the letters A, B, C, with numerical suffixes and dashes. Suffixes have been used to designate similar series standing isolated and dashes when they overlap. Thus A_1, A_1' define two overlapping series of similar structure, forming the group A_1. A_2, A_2' would then stand for a separate group, A_2, of two overlapping series, similar in structure with the series in group A_1, and so on. All these series having similar structure when spoken of generally are designated as those of *class* A. Series of the B class would then refer to another set of similar series, having their structure different from those of class A, and similarly for the series of the C class. When three or four similar series form an overlapping group, they have been designated by successively increasing the number of dashes. Thus B_1, B_2, B_2', B_2'', B_2''' refer to five similar series in CaF_2, one of which, B_1, is isolated from the rest, which form the group B_2 (see Plate 6, fig. III).

In the following Tables, besides the new series of bands, the first two heads of the already known series have been included, as it will be necessary to refer to them in the selection of the homologous series, on the basis of which certain relations have been found.

All the bands—old and new—have been put into the series form—using an equation of the type

$$\nu = a - bm - cm^2, \tag{1}$$

which is really a modification of Deslandres' formula

$$\nu = a - (bm + c)^2, \tag{2}$$

used by the previous observers. The constants of equation (1) are related to those of (2) as follows:—

$$a \text{ of } (1) = a - c^2 \text{ of } (2),$$

$$b \text{ of } (1) = 2bc \text{ of } (2),$$

$$c \text{ of } (1) = b^2 \text{ of } (2).$$

The equation (1) has the advantage that all the constants have a definite meaning; thus a is the end constant, and $= \nu_0$ (the wave number of the first head), $c =$ half the second difference of the wave numbers, and this being a small quantity, b gives approximately the average differences of the wave numbers between the consecutive heads.

3. *The Bands of Magnesium Fluoride.*

Magnesium fluoride presents three groups of bands, which are all in the ultra-violet between λ 3468 and λ 3686, and all fading toward the more refrangible side. The middle group, B_1, is by far the strongest, and consists of four overlapping series of bands. Owing to similarity in structure, these have been called, B_1, B_1', B_1'', B_1''', after the series of the same designation in the bands of CaF_2 and SrF_2. The other two groups are of about equal intensity, and, as there are no corresponding bands in the spectra of the fluorides of the other elements, the more refrangible group has been called D_1, and the less refrangible one E_1 (see fig. I, Plate 6).

In the D_1 group the band heads occur in pairs, and the two series have been named D_1 and D_1'. This group is somewhat similar in appearance to the A_3 or A_4 group of CaF_2, but the presence of a second component to some of the stronger heads marks out a dissimilarity in structure. The E_1 group is more complex, consisting of alternating double and single heads. Proceeding toward the ultra-violet the interval from a doublet to a singlet is rather smaller than that from the singlet to the next doublet. The heads, therefore, appear to occur in groups of three, which have been designated as E_1 and E_1' for the double head and E_1'' for the single one.

Some of the bands of the B_1 and D_1 groups have been previously observed by Olmsted but he did not attempt any grouping into series. It is, however, surprising that the equally intense group E_1 on the less refrangible side was not observed before.

Table I.—Constants for the Calculation of Series in MgF_2.

Series.	$a = \nu_0$.	*b.*	*c.*
D_1	28543·38	−20·98	+0·11
D_1'	28535·88	−20·91	+0·11
B_1	27861·28	−28·05	+0·015
B_1'	27825·47	−28·85	+0·015
B_1''	27814·55	−28·2601	+0·015
B_1'''	27775·61	−27·57	—
E_1	27149·43	−36·475	+0·175
E_1'	27145·44	−36·435	+0·1786
E_1''	27123·57	−36·7101	+0·1365

Table II.—MgF_2 Bands.

Series.	m.	Datta λ.I.A. (air).	ν (vac.).	$\nu_0 - \nu_c$.	m.	Datta λ.I.A. (air).	ν (vac.).	$\nu_0 - \nu_c$.	Series.	Second heads to D_1'.
D_1	0	3502·44	28543·37	−0·01	0	3503·36	28535·88	0·00	D_1'	3503·30
	1	3499·88	564·24	−0·01	1	00·81	556·66	−0·02		00·62
	2	97·35	584·90	0·00	2	3498·29	577·22	−0·04		3498·10
	3	94·84	605·35	+0·02	3	95·80	597·57	−0·06		95·56
	4	92·41	625·41	−0·13	4	93·31	617·96	+0·20		93·11
	5	90·08	644·43	−1·10	5	90·88	637·95	+0·27		90·61
	6	87·54	665·37	+0·07	6	88·48	657·56	+0·18		88·33
	7	85·17	684·78	−0·07	7	86·11	677·04	+0·18		86·0
	8	82·81	704·21	+0·03	8	83·78	696·21	+0·09		
	9	80·50	723·25	−0·04	9	81·48	715·25	+0·09		
	10	78·33	741·16	−1·02	10	79·19	734·15	+0·17		
	11	76·32	757·86	−2·99	11	76·96	752·56	−0·02		
					12	74·73	771·01	+0·05		
					13	72·55	789·08	−0·04		
					14	70·48	806·24	−0·82		
					15	68·46	823·01	−2·77		
B_1	0	3588·19	27861·28	0·00	0	3592·80	27825·47	0·00	B_1'	
	1	84·59	889·26	−0·05	1	89·11	854·15	+0·05		
	2	80·98	917·36	+0·04	2	85·42	882·80	+0·09		
	3	77·41	945·21	−0·08	3	81·80	911·13	−0·13		
	4	73·79	973·51	+0·11	4	78·06	940·15	−0·26		
	5	70·28	28001·15	−0·14	5	74·48	969·12	−0·22		
					6	71·98	993·95	−2·69		
B_1''	0	3594·22	27814·55	0·00	0	3599·26	27775·61		B_1'''	
	1	90·58	842·74	−0·05	1	95·69	803·18			
	2	86·94	871·00	−0·01						
	3	83·30	899·30	+0·10						
	4	79·66	927·50	+0·09						
	5	76·09	955·53	+0·05						
	6	72·65	983·07	−0·50						
	7	68·0	28011·20	−0·42						
E_1	0	3682·28	27149·43	0·00	0	3682·82	27145·44	0·00	E_1'	
	1	77·36	185·73	0·00	1	77·92	181·69	−0·09		
	2	72·50	221·70	+0·02	2	73·06	217·60	−0·05		
	3	67·69	257·31	+0·05	3	68·26	253·13	+0·02		
	4	62·96	292·58	+0·08	4	63·52	288·33	+0·07		
	5	58·28	327·48	+0·10	5	58·87	323·15	+0·00		
	6	53·57	362·70	+0·79	6	54·25	357·61	−0·01		
	7	49·04	396·66	+0·59	7	49·69	391·72	+0·06		
	8	very faint			8	45·19	425·50	+0·08		
	9	”			8	40·76	458·90	+0·12		
					10	36·42	491·71	0·00		
					11	32·20	524·62	−0·82		
E_1''	0	3685·79	27123·57	0·00	6	3656·73	27338·99	+0·06	E_1''	
	1	80·80	160·14	+0·02	7	52·07	373·86	+0·07		
	2	75·91	196·44	+0·01	8	47·46	408·52	0·00		
	3	71·04	232·47	−0·02	9	42·93	442·91	−0·24		
	4	66·23	268·23	0·00	10	38·41	477·03	−0·27		
	5	61·46	303·71	+0·04	11	33·94	510·87	−0·75		

4. *The Bands of Calcium Fluoride.*

Calcium fluoride shows seven groups of bands, of which five are in the visible spectrum, already well known, and two in the ultra-violet, previously unrecorded. Proceeding toward the red they have been designated as A_1, A_2, A_3, A_4; B_1, B_2; and C_1 respectively, in accordance with the terminology explained before. The new ultra-violet groups are too weak and complex (owing to the superposition of oxide bands), for satisfactory reproduction; only a sketch has therefore been given below to explain their structure (fig. 1).

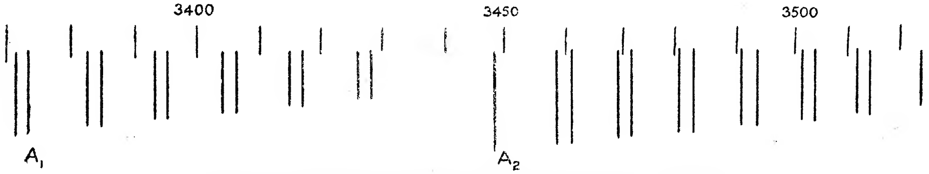

Fig. 1.—Structure of the groups A_1 and A_2 in CaF_2.

The Groups A_1, A_2, A_3 and A_4 are similar in structure as is indicated by their nomenclature. All of them fade toward the red and have double heads (Plate 6, fig. II). Groups B_1 and B_2 fade off toward the violet, the successive intervals between the heads decreasing very rapidly. Group B_1 consists of only one series of weak bands and is remarkable as having the "tail" (marked with black dots) stronger than the head. Group B_2 consists of four overlapping series, the "tails" of two of which (B_2, B_2'') are clearly recognisable (Plate 6, fig. III). Group C_1 consists of two overlapping series C_1, C_1', fading towards the violet. But as the successive intervals between the heads decrease very slowly, their appearance is quite different from those of B.

The B_2 and C_1 groups of bands, though previously known, have been remeasured, as a greater number of heads has been observed in each series. Their series formulæ have also been recalculated.

Table III.—Constants for the Calculation of Series in CaF_2.

Series.	$a = \nu_0$.	b.	c.	Series.	$a = \nu_0$.	b.	c.
A_1	29655·02	+100·61	−1·0	B_1	17094·8	− 6·006	+0·1764
A_1'	29636·74	+101·001	−1·0	B_2	16559·15	− 5·6201	+0·155
A_2	28983·70	+ 90·5002	−0·7	B_2'	16521·72	− 5·4002	+0·155
A_2'	28876·70	+ 90·2001	−0·8	B_2''	16484·87	− 5·6003	+0·155
A_3	19428·5	+ 24·242	+0·1426	B_2'''	16424·27	− 5·2401	+0·155
A_3'	19424·8	+ 24·191	+0·1419	C_1	15978·94	−11·3001	+0·150
A_4	18894·9	+ 20·6018	+0·1029	C_1'	15905·89	−11·0003	+0·120
A_4'	18888·1	+ 20·4766	+0·1017				

Table IV.—CaF_2 Bands.

Series.	m.	Datta λ.I.A. (air).	ν (vac.).	$\nu_0-\nu_c$.	m.	Datta λ.I.A. (air).	ν (vac.).	$\nu_0-\nu_c$.	Series.
A_1	0	3371·15	29655·02	0·00	0	3373·22	29636·74	0·00	A_1'
	1	82·62	555·41	0·00	1	84·64	536·77	+0·03	
	2	93·71	457·85	+0·05	2	95·93	438·61	−0·13	
	3	3404·76	363·28	+0·09	3	3407·02	342·72	−0·02	
	4	15·66	268·52	−0·06	4	18·00	248·57	−0·17	
	5	26·42	176·64	−0·33	5	28·73	156·98	+0·24	
A_2	0	3449·24	28983·66	−0·04	0	3462·02	28876·70	0·00	A_2'
	1	59·95	893·88	−0·02	1	72·78	787·25	−0·05	
	2	70·59	805·33	−0·17	2	83·41	699·35	−0·15	
	3	81·19	718·47	−0·03	3	93·96	612·71	−0·59	
	4	91·60	631·96	−0·94	4	3504·23	528·79	+0·09	
	5	3501·80	548·59	−0·12	5	14·46	445·78	+0·08	
	6	11·84	467·00	+1·1	6	24·54	364·45	+0·15	
A_3 (Fabry A_1)	0	5145·668	19428·5		0	5146·648	19424·8		A_3' (Fabry A_2)
	1	52·246	403·7		1	53·229	400·0		
	...	......	......		...	......	......		
	18	5276·663	18946·2		18	5277·583	18942·9		
A_4 (Fabry B_1)	0	5290·993	18894·9		0	5292·899	18888·1		A_4' (Fabry B_2)
	1	96·882	873·9		1	98·623	867·7		
	...	......	......		...	......	......		
	20	5420·994	441·8		20	5422·112	438·0		
B_1 (Fabry C)	0	5848·142	17094·8						
	1	46·258	100·6						
	...	......	......						
	10	33·635	137·3						
Datta B_2 (Fabry D)	0	6037·29	16559·15	0·00	0	6050·97	16521·72	0·00	Datta B_2' (Fabry D′)
	1	35·30	564·60	−0·01	1	49·03	527·01	+0·04	
	2	33·40	569·82	+0·05	2	47·22	531·96	+0·06	
	3	31·62	574·71	+0·09	3	45·58	536·44	−0·08	
	4	29·98	579·21	+0·06	4	43·98	540·82	−0·02	
	5	28·43	583·47	+0·10	5	42·56	544·71	−0·13	
	6	27·07	587·21	−0·08	6	41·23	548·35	−0·23	
	7	25·78	590·76	−0·13	7	39·96	551·99	+0·07	
	8	24·55	594·16	−0·03					
Datta B_2'' (Fabry D″)	0	6064·5	16484·87	0·00	0	6086·87	16424·27	0·00	Datta B_2''' (Fabry D‴)
	1	62·47	490·38	+0·07	1	84·99	429·34	−0·01	
	2	60·57	495·52	+0·07	2	83·22	434·12	−0·01	
	3	58·81	500·34	+0·06	3	81·56	438·58	−0·02	
	4	57·14	504·89	+0·10	4	80·04	442·72	−0·03	
	5	55·62	509·04	+0·04	5	78·66	446·45	−0·15	
	6	54·23	512·82	−0·07	6	77·53	449·50	−0·63	
	7	52·93	516·37	−0·11	7	76·23	453·05	−0·31	
	8	51·93	519·10	−0·65	8	74·81	456·87	+0·60	
					9	73·84	459·52	+0·65	

Table IV.—CaF_2 Bands—(*contd.*).

Series.	*m.*	Datta λ.I.A. (air).	ν (vac.).	$\nu_0 - \nu_c$.	*m.*	Datta λ.I.A. (air).	ν (vac.).	$\nu_0 - \nu_c$.	Series.
Datta C_1 (Fabry E)	0	6256 ·52	15978 ·94	0 ·00	0	6285 ·25	15905 ·89	0 ·00	Datta C_1' (Fabry E′)
	1	52 ·14	990 ·12	+0 ·03	1	80 ·95	916 ·75	−0 ·02	
	2	47 ·94	16000 ·86	−0 ·08	2	76 ·72	927 ·49	+0 ·08	
	3	43 ·72	011 ·68	+0 ·19	3	72 ·67	937 ·78	−0 ·03	
	4	39 ·77	021 ·82	+0 ·08	4	68 ·57	948 ·20	+0 ·23	
	5	36 ·03	031 ·42	−0 ·27	5	64 ·68	958 ·10	+0 ·21	
	6	32 ·28	041 ·07	−0 ·27	6	60 ·96	967 ·58	+0 ·01	
	7	28 ·56	050 ·64	−0 ·05	7	57 ·37	976 ·74	−0 ·27	
	8	25 ·47	058 ·61	−1 ·13	8	54 ·12	985 ·07	−1 ·14	
	9	22 ·54	066 ·16	−2 ·33	9	50 ·31	994 ·80	−0 ·37	
					10	46 ·53	16004 ·48	+0 ·59	

5. *The Bands of Strontium Fluoride.*

Strontium fluoride shows eleven groups of bands, of which nine are in the visible spectrum and two in the ultra-violet. Excepting one in the visible region (designated as B_2, Plate 6, fig. IV) and the two in the ultra-violet (designated as A_1 and A_2), all were previously known. Proceeding toward the red, these known groups are designated as A_3, A_4, B_1, B_2, B_3, C_1, C_2, C_3, and C_4 repectively (Plate 6, figs. IV and V). The new ultra-violet groups are too weak for satisfactory reproduction, and also complex owing to the superposition of oxide bands; only a sketch has therefore been given below to explain their structure (fig. 2).

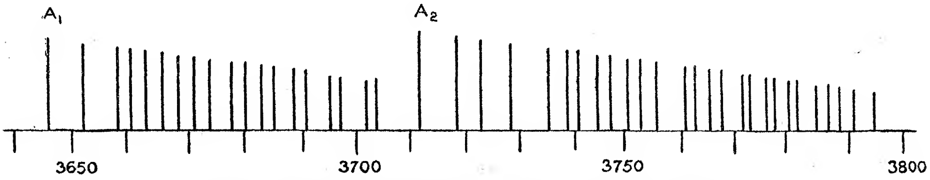

Fig. 2.—Structure of the groups A_1 and A_2 in SrF_2.

The groups A_1, A_2, A_3 and A_4 are similar in structure, all of them fading toward the red. These have double heads and are similar to the corresponding groups in CaF_2. Groups of the B and C class fade toward the violet, but the structure of the B class is quite different from that of the C class. As in the corresponding groups in CaF_2, the successive intervals between the heads decrease very rapidly in the B class, these having well pronounced "tails." The tails of B_1 and B_3 have been marked with dots (Plate 6, fig. IV). The group B_2 is very weak and has been photographed with 30 minutes' exposure.

Table V.—Constants for the Calculation of Series in SrF_2.

Series.	$a = \nu_0$.	b.	c.	Series.	$a = \nu_0$.	b.	c.
A_1	27417·16	+44·35	−0·22	B_3	15578·921	− 3·3203	+0·0443
A_1'	27309·72	+44·70	−0·12	C_1	15356·300	− 7·8989	+0·0592
A_2	26929·35	+41·001	−0·20	C_1'	15319·617	− 8·0935	+0·0592
A_2'	26740·04	+40·801	−0·41	C_2	15076·973	− 7·8733	+0·0549
A_3	17764·15	+11·732	+0·0417	C_2'	15025·049	− 7·6006	+0·0542
A_3'	17764·15	+12·0204	+0·0391	C_3	14860·720	−12·4036	+0·07472
A_4	17325·104	+ 9·4831	+0·0347	C_3'	14835·25	−12·085	+0·05166
A_4'	17302·615	+ 8·9796	+0·04405	C_4	14557·99	−11·769	+0·03753
B_1	15857·83	− 3·4908	+0·0531	C_4'	14557·99	−11·9023	+0·05419
B_2	15787·93	− 3·7001	+0·0901				

Table VI.—SrF_2 Bands.

Series.	m.	λ.I.A. (air).	ν (vac.).	$\nu_0 - \nu_c$.	m.	λ.I.A. (air.)	ν (vac.).	$\nu_0 - \nu_c$.	Series.
Datta A_1	0	3646·29	27417·16	0·00	0	3660·66	27309·72	0·00	Datta A_1'
	1	52·17	373·03	0·00	1	66·64	265·20	+0·06	
	2	58·01	329·27	−0·07	2	72·63	220·73	−0·07	
	3	63·82	285·95	−0·14	3	78·59	176·65	−0·05	
	4	69·59	243·06	−0·22	4	84·54	132·70	−0·14	
	5	75·27	200·96	0·00	5	90·42	089·48	+0·26	
	6	80·97	158·85	−0·13	6	96·26	046·69	+0·85	
	7	86·56	117·62	+0·13	7	3702·15	003·67	+0·97	
	8	92·13	076·79	+0·20					
	9	97·70	035·95	+0·12					
	10	3703·12	26996·38	+0·72					
Datta A_2	0	3712·36	26929·35	0·00	0	3738·65	26740·04	0·00	Datta A_2'
	1	18·02	888·45	−0·10	1	44·31	699·63	−0·02	
	2	23·60	848·09	−0·06	2	49·88	659·99	−0·09	
	3	29·16	808·14	−0·01	3	55·58	619·46	−1·87	
	4	34·66	768·60	+0·05	4	60·81	582·52	−0·91	
	5	40·02	730·32	+0·97	5	65·99	545·90	+0·29	
	6	45·56	690·66	+0·11	6	71·09	510·08	+0·08	
	7	50·98	652·17	+0·02	7	76·14	474·57	+0·04	
	8				8	81·07	440·06	+0·18	
	9	61·66	576·45	−0·10	9	85·79	406·34	+1·08	
	10	66·93	539·28	−0·07	10	90·710	372·84	−0·22	
	11	72·0	503·62	+1·07	11	95·55	339·22	−1·63	
	12	77·29	466·51	+0·36					
	13	82·44	430·48	+0·33					
	14	87·75	393·37	−1·16					
	15	92·93	357·41	−1·94					
A_3 (Leopold A_1)			(air)				(air)		A_3' (Leopold A_2)
	0	5629·316	17764·148		0	5629·316	17764·148		
	1	33·086	752·259		1	33·086	752·259		
	...	......	......		...	......	......		
	29	5750·57	389·58		29	5752·57	383·53		

Table VI.—SrF_2 Bands—(*contd.*).

Series.	m.	λ.I.A. (air).	ν (vac.).	$\nu_0-\nu_c$.	m.	λ.I.A. (air).	ν (vac.).	$\nu_0-\nu_c$.	Series.
A_4 (Leopold B_1)	0	5771·971	17325·104		0	5779·473	17302·615		A_4' (Leopold B_2)
	1	74·822	316·551		1	82·169	294·548		
	...	......	......		...	......	......		
	9	98·511	245·806		26	5859·542	066·180		
B_1 (Leopold D)	0	6306·032	15857·832		0	6332·20	(vac.) 15787·93	0·00	Datta B_2.
	1	04·721	861·130		1	30·74	791·57	+0·03	
	...	......	......		...	......	......		
	23	6285·02	910·85		2	29·39	794·94	−0·03	
					3	28·11	798·14	−0·08	
					4	26·88	801·21	−0·08	
B_3 (Leopold D″)	0	6418·927	15578·921		5	25·72	804·10	−0·08	
	1	17·687	581·937		6	24·60	806·90	+0·01	
	...	......	......		7	23·56	809·50	+0·08	
	24	6397·406	631·335		8	22·54	812·08	+0·31	
					9	21·55	814·53	+0·59	
C_1 (Leopold E)	0	6511·985	15356·300		0	6527·578	(air) 15319·617		C_1' (Leopold E′)
	1	08·676	364·107		1	24·158	327·648		
	...	......	......		...	......	......		
	15	6467·70	461·45		7	04·71	373·48		
C_2 (Leopold E″)	0	6632·631	15076·973		0	6655·552	15025·049		C_2' (Leopold E‴)
	1	29·324	084·494		1	52·091	032·867		
	...	......	......		...	......	......		
	15	6588·199	178·655		6	35·562	070·313		
C_3 (Leopold F)	0	6729·15	14860·72		0	6740·70	14835·25		C_3' (Leopold F′)
	1	23·80	872·54		1	35·16	847·46		
	...	......	......		...	......	......		
	8	6687·13	954·10		11	6683·18	962·94		
C_4 (Leopold F″)	0	6869·08	14557·99		0	6869·08	14557·99		C_4' (Leopold F‴)
	1	63·39	570·06		1	63·39	570·06		
	...	......	......		...	......	......		
	19	6773·33	763·79		19	6772·93	764·66		

6. *The Bands of Barium Fluoride.*

Barium fluoride shows four groups of bands, which are all in the visible region between λ 4937 and λ 5160 and were already well known. Proceeding toward the red, they were designated as A, B, C, and E by George, but their nomenclatures have been altered to B_1, B_2, C_1, and B_3 respectively, in accordance with the groups of CaF_2 and SrF_2, with which they are believed to be homologous.

Although the bands of BaF_2 fade in the opposite direction, *i.e.*, towards the red, the structure of the B_1, B_2, C_1, and B_3 groups are similar to the corresponding groups in CaF_2. Their " tails " are likewise clearly recognisable and have been marked with dots (Plate 6, fig. VI).

The group designated as D by George was never observed. In this connection it may be mentioned that unless the arc is very well supplied with the salt (BaF_2) fine flutings always appear as a sort of background to the stronger bands of BaF_2. These become very weak when the arc is well supplied with BaF_2 and they strengthen with BaO. It is therefore quite likely that these bands are due to the oxides.

In the ultra-violet there appears a sharp head at λ 3810, followed by a series of fine flutings, which have no homologues elsewhere. It has been previously observed by Olmsted.

Table VII.—Constants for the Calculation of Series in BaF_2.

Series.	$a = \nu_0$.	*b*.	*c*.
B_1	20253·837	+ 6·1092	−0·1833
B_2	20198·75	+ 6·5375	−0·1695
C_1	20031·41	+11·5539	−0·14903
C_1'	19997·35	+11·9478	−0·1278
B_3	19534·47	+ 8·3066	−0·15404

Table VIII.—BaF_2 Bands.

Series.	*m*.	λ (air).	ν (air).	*m*.	λ (air).	ν (air).	Series.
B_1 (George A)	0	4937·336	20253·837	0	4950·802	20898·75	B_2 (George B)
	1	38·812	47·780	1	52·612	91·37	
	...	......	......	...	......	......	
	9	47·315	12·98	18	71·70	13·84	
C_1 (George C)	0	4992·146	20031·41	0	5000·662	19997·35	C_1' (George C′)
	...	......	......	...	......	......	
	8	5012·859	19948·70	29	52·307	753·84	
B_3 (George E)	0	5119·157	19534·47				
	1	21·296	526·31				
	...	......	......				
	17	43·949	440·32				

7. *Remarks on the CaF_2 Bands. Orange Group B_2 (Series B_2, B_2', B_2'', B_2''').*

The series of bands designated H_1, H_2, H_3, H_4, and assigned to SrF_2 by Leopold, and those called F_1, F_2, F_3 by George, and attributed by him to BaF_2, have not been included in the tables of Sr and Ba, for the simple reason that they are really due to CaF_2. A comparison of the measurements of Leopold and George with each other and with the wave-lengths of the orange series of CaF_2 given by Rosch, as in the following Table, clearly show their identity:—

m.	Rosch—CaF_2. λ I.A. (air).	Leopold—SrF_2. λ I.A. (air).	George—BaF_2. λ I.A. (air).
	$D\ (B_2)$.	H_1.	F_1.
0	6037·153	6036·908	6036·869
1	35·039	34·831	34·820
2	33·251	32·934	32·875
3	31·327	31·099	31·083
4	29·654	29·451	29·400
	$D'\ (B_2')$.	H_2.	F_2.
0	6051·034	6050·819	6050·705
1	48·947	48·78	48·706
2	47·156	46·97	46·860
3	45·474	45·10	45·055
4	43·939	43·85	43·439
	$D''\ (B_2'')$.	H_3.	F_3.
0	6064·612	6064·395	6064·380
1	62·627	62·344	62·310
2	60·643	60·431	60·378
3	58·880	58·653	58·581
4	57·192	57·026	56·934
5	55·668	55·457	55·412
6	54·295	54·14	54·010
	$D'''\ (B_2''')$.	H_4.	
0	6084·985	6084·24	
1	81·565	81·51	
2	80·040	79·53	
3	76·225	76·98	
4	74·810	75·24	

All the different observers agree that with the increase of molecular weight the homologous bands are shifted towards the red. Consequently it seems improbable that exactly similar groups of bands of CaF_2, SrF_2, and BaF_2 would occupy the same position. If SrF_2 and BaF_2 have really similar groups, we should expect them in the red and infra-red respectively.

With these doubts, the following observations were made, which clearly show that the group in question really belongs to CaF_2.

Several comparison photographs were taken in which CaF_2 formed the outer spectrum and either SrF_2 or BaF_2 formed the inner one. This group was then found to be identical in position with the orange group B_2 of CaF_2, but of much lower intensity.

This orange group is the most sensitive in the spectrum of CaF_2. The arc between hard carbon rods, which contain very little CaF_2, shows this group faintly, and it becomes more intense when the arc is fed by a compound of calcium other than the fluoride. Thus a few plates of CaO spectrum were obtained where this group was superposed on the spectrum of the oxide. It is very likely that the appearance of this group in the spectrum of SrF_2 and BaF_2 is due to CaF_2 present in the carbon rod itself. BaF_2 in a copper arc or in the oxy-coal gas flame did not show it at all. Hence it is believed that this group really belongs to CaF_2.

8. *The Relation between the Spectrum of the Alkaline Earth Fluorides.*

Possible relations among the band spectra of nearly related compounds are to be expected from the occurrence of similar series in the different spectra. In the spectra of MgF_2, CaF_2, and SrF_2, such series can be picked out quite readily. The structure of the series and its position relative to the molecular weight of the compound, assisted by the direction in which it shades off, give us the best guidance for such selection. The following three classes have thus been identified:—

Class A—

(*a*) The ultra-violet groups A_1, A_2 of CaF_2.
(*b*) The blue-green and the green groups A_3, A_4 of CaF_2.
(*c*) The ultra-violet groups A_1, A_2 of SrF_2.
(*d*) The green and the yellow groups A_3, A_4 of SrF_2.

These have the following similarity:—All of them fade toward the red; the bands of SrF_2 are more toward the red than the corresponding bands of CaF_2; they present the appearance of pair series, a head of A_1 with one of A_1', a head of A_2 with one of A_2', and so on (figs. II and IV).

Class C—

(*a*) The red group C_1 of CaF_2.
(*b*) The red groups C_1, C_2, C_3, and C_4 of SrF_2.

All these shade off towards the violet. The bands of SrF_2 are further in the red than those of CaF_2; they present the same fluted appearance, and the arrangement is also similar, for in each group we find the second series to be in advance of the first by a few heads, C_1' in advance of C_1, C_2' of C_2, etc.

Class B—

(*a*) The strong ultra-violet group B_1 of MgF_2.
(*b*) The yellow-green group B_1 of CaF_2.
(*c*) The orange group B_2 of CaF_2.
(*d*) The red groups B_1, B_2, and B_3 of SrF_2.

These have the following similarity:—They all fade towards the red and form the most intense group in the respective spectra (the group B_1 of CaF_2 and the group B_2 of SrF_2 are, however, weak); their positions are consistent with their increasing molecular weight and they all have a typical fluted structure totally different from those of class A and C.

In this classification, BaF_2 bands present an anomaly as to their positions in the blue region, but on the similarity of structure the groups B_1, B_2, B_3 and C_1 respectively appear to be homologous with the B_1, B_2, B_3 and C_1 groups of SrF_2.

The classification of practically all the series in the spectra of the alkaline earth fluorides in the above way provides a basis for the further investigation of possible relationship between the characteristics of the various series of bands and the molecular weights of the respective compounds. Of the numerous formulæ tried, the one of the two which represents the facts of observation most closely, is

$$\frac{\log b \times \sqrt{(m')}}{a} = \text{const.},$$

where a and b are the numerical values of the constants used in calculating the series and m' is the molecular weight of the compound.

The 4th column of the Table on opposite page shows how closely the formula applies to the different groups in each class.

We thus find that in each class the values of $\frac{\log b \times \sqrt{(m')}}{a}$ agree well with each other, although varying from one class to another. It is a remarkable fact that the value for class C is very close to that for class A. This is what we should expect when we notice that the series of the C class resemble those of the A class, both fading off very slowly, though in opposite directions.

In seeking relations between the nearly related compounds, some function of the molecular number—a conception of Dr. H. S. Allen* which means the sum total of the nucleus positive charge in the molecule and which plays a part like the atomic number in the elements—was thought worth trying, and hence a separate column introducing molecular number M instead of molecular weight m', has been calculated. This gives a better agreement between the values as given in the 5th column of the preceding Table when instead of $\sqrt{(M)}$, $\log M$ is used. The logarithmic function of the atomic number has best answered the relations between the allied elements; hence the introduction of log M seems to be on the right path, and the formula adopted becomes

$$\frac{\log b \times \log M}{a} = \text{constant}.$$

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* Dr. H. S. Allen, 'Phil. Mag.,' vol. 35 (1918).

Homologous series.	$a = \nu_0$.	b.	$\frac{\log b \times \sqrt{(m')}}{a}$.	$\frac{\log b \times \log M}{a}$.
CaF_2 A_1	29655·02	100·61	5·964 × 10^{-4}	10·67 × 10^{-5}
„ A_1'	29636·74	101·001	5·973	10·68
„ A_2	28983·70	90·5002	5·962	10·66
„ A_2'	28876·70	90·2001	5·979	10·69
„ A_3	19428·5	24·242	6·293	11·26
„ A_3'	19424·8	24·191	6·290	11·25
„ A_4	18894·9	20·6018	6·141	10·98
„ A_4'	18888·1	20·4766	6·130	10·99
SrF_2 A_1	27417·16	44·35	6·731	10·51
„ A_1'	27309·72	44·70	6·772	10·56
„ A_2	26929·35	41·001	6·711	10·47
„ A_2'	26740·04	40·801	6·750	10·53
„ A_3	17764·15	11·732	6·746	10·63
„ A_3'	17764·15	12·0204	6·812	10·63
„ A_4	17325·1	9·4831	6·206	9·86
„ A_4'	17302·61	8·9796	6·012	9·63
CaF_2 C_1	15978·94	11·3001	5·782 × 10^{-4}	10·34 × 10^{-5}
„ C_1'	15905·89	11·0003	5·820	10·41
SrF_2 C_1	15356·30	7·8989	6·550	10·21
„ C_1'	15319·617	8·0935	6·572	10·36
„ C_2	15076·973	7·8733	6·660	10·39
„ C_2'	15025·049	7·6009	6·569	10·36
BaF_2 C_1	20031·41	11·9478	7·126	10·05
„ C_1'	19997·35	11·5539	7·048	9·93
MgF_2 B_1	27861·28	28·05	4·103 × 10^{-4}	7·67 × 10^{-5}
„ B_1'	27825·47	28·85	4·143	7·75
„ B_1''	27814·55	28·2601	4·120	7·70
„ B_1'''	27775·61	27·57	4·012	7·12
CaF_2 B_1	17094·8	6·006	4·022	7·19
„ B_2	16559·15	5·6201	3·998	7·15
„ B_2'	16521·72	5·4002	3·915	7·00
„ B_2''	16484·87	5·6003	4·007	7·17
„ B_2'''	16424·27	5·2401	3·867	6·92
SrF_2 B_1	15857·83	3·4908	3·836	5·99
„ B_2	15787·93	3·7001	4·033	6·29
„ B_3	15578·921	3·3203	3·721	5·85
BaF_2 B_1	20253·837	6·5375	5·335	7·52
„ B_2	20198·75	6·1092	5·109	7·20

The molecular numbers of the compounds used are:—

$$MgF_2 = 12+2\times 9 = 30, \qquad SrF_2 = 38+2\times 9 = 56,$$
$$CaF_2 = 20+2\times 9 = 38, \qquad BaF_2 = 56+2\times 9 = 74.$$

These formulæ thus give relations between the wave number of the first head in the series, the average difference in wave number between the consecutive heads, and the molecular weight or molecular number. The fact that the calculated values of the above relations come out as constants may be interpreted in the following way:—The mechanism of emission of bands of the similar compounds of the same periodic group is essentially the same, they emit the same types of bands, so that if the system owing to their possessing greater energy or lesser mass appear on the high frequency side, the successive band heads will be more widely separated, *i.e.*, will have a greater frequency difference, and if owing to either lesser energy or greater mass they appear on the low frequency side, the successive heads will be closer together.

Beryllium fluoride bands, previously unknown, have also been observed, and, from their positions and separations, it is expected that they will agree with the above formula. It is hoped to discuss them in a separate paper.

9. *A New Relation.*

A striking feature of the series of the B class is that they show a strong line on the side in which they fade off, and this may be mistaken for the head of the series.* It is, however, possible to arrive at an explanation of the appearance of this line in the following way. In all these series the successive intervals of the heads gradually decrease, till finally the heads come too close to be resolved (see figs IV, etc.). The strong line on the shading side, which has been named as the "tail" of the series, may thus be regarded as due to the crowding of several unresolved heads in a finite space. The intensity of the tail would therefore depend on the number of heads crowding, and their respective intensity. The falling off of intensity in the B_1 series of CaF_2 is less gradual than that in its B_2 series, and, at the same time, the rate of decrease of intervals between the successive heads is faster in the former than in the latter. Both these factors thus contribute to the crowding of stronger lines to form the tail of the B_1 series. Hence, although the general intensity of the B_2 series is greater, the tail of B_1 appears much more striking than that of B_2, and gives the false appearance of the head.

The B class series, with diminishing intervals, are all expressed by the equation $\nu = a - bm - cm^2$, in which b and c have values of opposite sign. Thus, for the nearest positive integral value of m, satisfying the condition $\partial\nu/\partial m = -b - 2cm = 0$, ν is a maximum or minimum depending on the sign of c. Near this value of m, since $\partial\nu/\partial m = 0$, there will be a crowding of lines. Theoretically, therefore, from a knowledge of b and c, the position of the tail, *i.e.*, the turning point, can be predicted, and the following Tables will show the closeness of the predicted values to the observed ones :—

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* With regard to the B class of bands in SrF_2, it may be remarked that two different interpretations have been given (Konen, 'Das Leuchten der Gase und Dämpfe,' pp. 238–241). Fabry, whose interpretations have been accepted in the present paper, has described the first line towards the red as the head of the series. Deslandres, on the other hand, took the strong line towards the violet—the one regarded as tail here—as the head. Konen suggested that as the strong line (tail) may possibly be due to a crowding of several heads, Fabry's interpretation is, perhaps, the more correct one.

Series.	m for which $d\nu/dm=0=-b/2c$.	$\nu_0 \sim \nu$ tail (cal.).	$\nu_0 \sim \nu$ tail (obs.).	Remarks.
CaF_2 B_1	17	51·12	49·6	The difference between the observed and the calculated value is within the limits of variations of the values of b and c so as to approximately satisfy the equation $\nu=a-bm-cm^2$.
„ B_2	18	50·94	48·7	
„ B_2''	18	50·58	49·4	
SrF_2 B_1	33	57·37	58·5	
„ B_3	36	60·8	57·4	
BaF_2 B_3	27	111·7	111·0	

For values of m equally greater or less than this critical value, the values of ν are almost equal, so that, with a low dispersion, the two heads practically coincide. With a high dispersion, however, a fainter head, corresponding to the greater value of m, is to be expected by the side of the stronger head, corresponding to the lower value of m.* For $m=(-b/c)$, $\nu_m=\nu_0$, and, for values exceeding $(-b/c)$, ν_m will be less than ν_0; if, therefore, the successive heads fall in intensity so slowly that the bands $m=-b/c+1$, $-b/c+2$, etc., are not very weak, we should expect one or more fainter heads, whose frequencies are less than that of the head ν_0. In the B_1 series of CaF_2, since the intensities fall off rather slowly, the thirty-fifth or the thirty-sixth band, corresponding to $m=-b/c+1$, $-b/c+2$ respectively, probably survive in intensity, and appear on the low frequency side of the head (ν_0). This, perhaps, explains the appearance of the two faint bands in front of the strong head in fig. III.

Another interesting fact observed is that the difference in frequency ($\Delta\nu$) between the head and tail in the homologous compounds is nearly constant for different series of the same compound, but varies from one to another, such that $\log \Delta\nu = K \log M$, where M is the molecular number. Thus :—

Series.	$\Delta\nu$.	M.	Log $\Delta\nu$.	Log M.	K.
CaF_2 B_1	49·6	38	1·695	1·58	1·06
„ B_2	48·7	38	1·687	1·58	1·06
„ B_2''	49·4	38	1·693	1·58	1·06
SrF_2 B_1	58·5	56	1·767	1·748	1·01
„ B_3	57·4	56	1·759	1·748	1·01
BaF_2 B_2	111·68	74	2·048	1·869	1·09
„ B_3	111·8	74	2·0484	1·869	1·09

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* Depending on the values of B and C, they may exactly coincide, in which case their separation is impossible.

The C class of series also should have tails, but, from the theoretical calculation, it is found that, in the C_1' series of CaF_2, the thirty-eighth band would correspond to the tail; as the series is very weak, the heads about the thirty-eighth band are too weak to give the impression of a tail. Though the corresponding series of SrF_2 is very strong, the tail would occur at the sixty-seventh band, and so the heads forming the tail are weak, and do not, therefore, show any clear tail.* But, even in this class, $\Delta\nu$ and M exhibit some indication of the previous relation, thus :—

Series.	m for max.	$\Delta\nu$ (calculated).	M.	Log $\Delta\nu$.	Log M.	K.
CaF_2 C_1'	38	212·6	38	2·327	1·58	1·47
SrF_2 C_1'	67	263·3	56	2·419	1·748	1·39
BaF_2 C_1'	47	290·2	74	2·462	1·869	1·35

The series C_1' of BaF_2 shows a tail, as is to be expected, considering the general intensity of the group. The observed $\Delta\nu = 296·8$ closely agrees with the calculated one.

10. *Summary.*

1. Nine series of bands have been found in the spectrum of MgF_2.

2. Four new series have been found for CaF_2 in the ultra-violet, and additional heads recorded in some of the series in the visible region.

3. Four new series have been found for SrF_2 in the ultra-violet and a very weak one in the red.

4. Series designated as H_1, H_2, H_3, H_4, and ascribed to SrF_2 by Leopold, also the same series called F_1, F_2, F_3, and allotted to BaF_2 by George, have been proved to be really due to CaF_2, and corresponding with its series now designated as B_2, B_2', B_2'', B_2'''.

5. The homologous series of the different alkaline earth fluorides have been connected by empirical equations, using the constants of the series equations and the molecular weight or the molecular numbers of the respective compounds.

6. An explanation has been given of the appearance of a "tail" in some of the bands, starting with their series equations. It has also been shown that the difference in wave numbers of the heads and tails of the similar series is constant for the same compound, but varies from one to another in a definite way.

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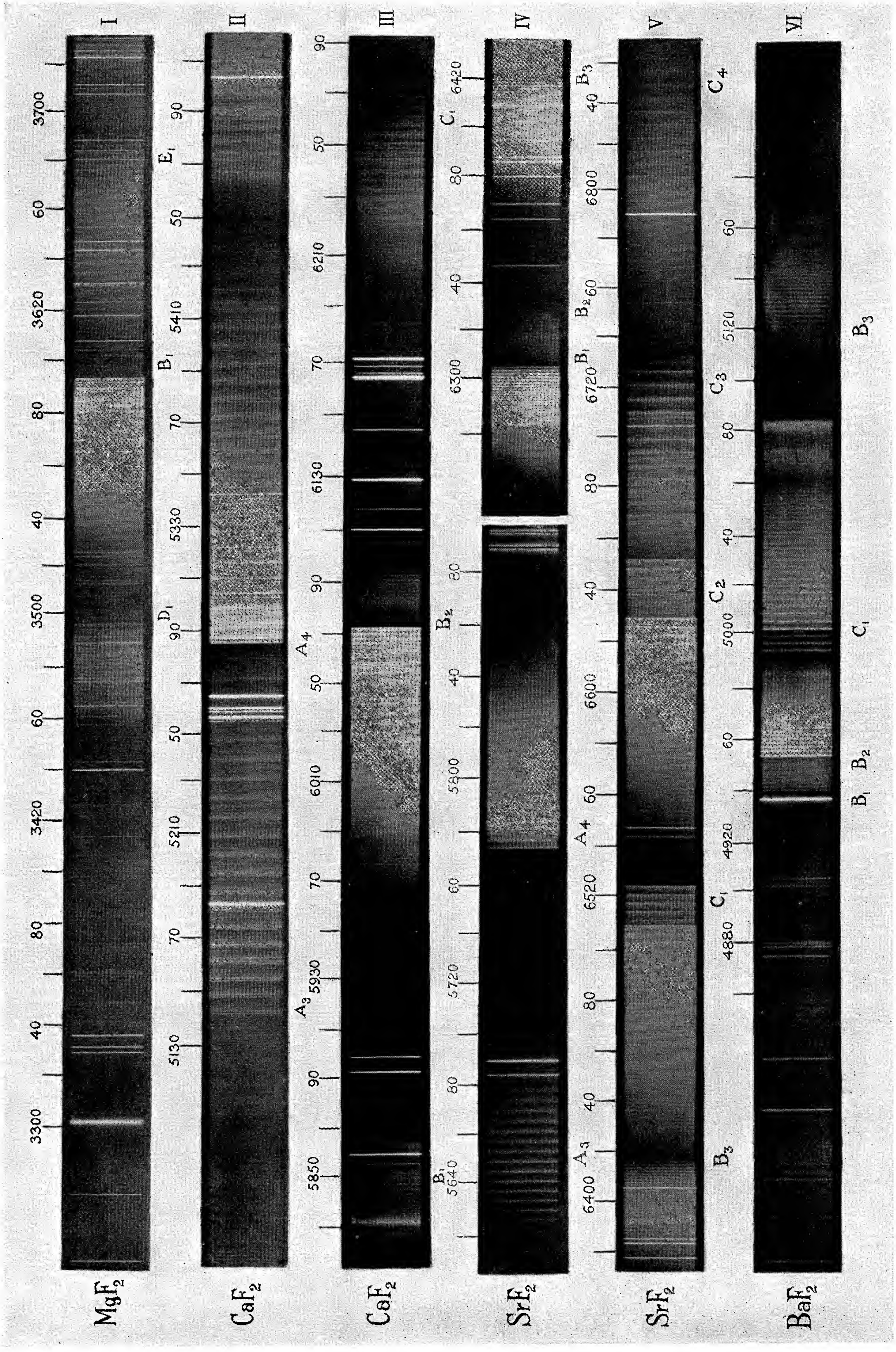
* In the series C_1 and C_1' of SrF_2, there are indications of faint tails near about the calculated positions; in C_2'' and C_2''' the calculated positions of the tails fall on the preceding series C_1 and C_1' respectively, hence they cannot possibly be detected.


I
MgF$_2$
3700
60
3620
80
40
3500
60
3420
80
40
3300
II
CaF$_2$
90
E$_1$
50
5410
B$_1$
70
5330
D$_1$
90
50
5210
70
5130
III
CaF$_2$
90
50
6210
70
6130
90
A$_4$
50
6010
70
A$_3$
5930
90
5850
IV
SrF$_2$
6420
C$_1$
80
40
6300
80
B$_2$
40
5800
60
5720
80
B$_1$
5640
V
SrF$_2$
B$_3$
40
6800
B$_2$
60
B$_1$
6720
80
40
6600
60
A$_4$
6520
80
40
A$_3$
6400
C$_4$
60
5120
C$_3$
80
40
C$_2$
5000
60
4920
C$_1$
4880
B$_3$
VI
BaF$_2$
B$_3$
C$_1$
B$_2$
B$_1$

In closing, I beg to thank Prof. A. Fowler, F.R.S., for the very valuable suggestions he was always most ready to give, and for the trouble he took in revising the paper, and also to Mr. W. Bradfield, for his help in producing the enlargements.

DESCRIPTION OF PLATE 6.

Fig. I.—Spectrum of MgF_2, region about λ 3460–λ3700. On the left is the group D_1, next comes B_1, and finally on the right there is the group C_1.

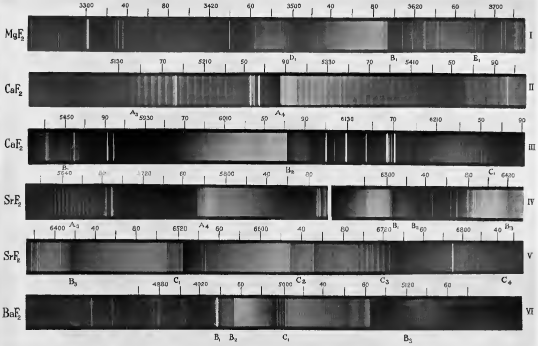
Fig. II.—Spectrum of CaF_2, region about λ 5145–λ 5430, having the group A_3 on the left and the group A_4 on the right.

Fig. III.—Spectrum of CaF_2, region about λ 5835–λ 6285. The group B_1 is on the left, the dot at about λ 5833 marks its "tail." The group B_2 comes next. The dot at about λ 6022 marks the "tail" of the series B_2, and that at about λ 6050 shows the "tail" of B_2''. On the right there is the group C_1. The dots are not very clear in the reproduction.

Fig. IV.—Spectrum of SrF_2 λ 5620–λ 6420. Proceeding towards the red, there are the groups A_3, A_4, B_1, B_2, and B_3, in succession. The dot at about λ 6284 marks the "tail" of the series B_1, and that at about λ 6394 shows the "tail" of the series B_3.

Fig. V.—Spectrum of SrF_2 λ 6380–λ 6870, showing the groups B_3, C_1, C_2, C_3, and C_4, from left to right.

Fig. VI.—Spectrum of BaF_2 λ 4937–λ 5160, showing the group B_1, B_2, C_1, and B_3, in succession from left to right. The dots mark the positions of the tails of the respective series.



3300 40 80 3420 60 3500 40 80 3620 60 3700
MgF₂
I
5130 70 5210 50 90 D₁ 5330 70 B₁ 5410 50 E₁ 90
CaF₂
II
5650 90 A₃ 5930 70 6010 50 A₄ 90 6130 70 6210 50 90
CaF₂
III
B₁ 5640 80 5720 60 5800 40 B₂ 80 6300 40 80 C₁ 6420
SrF₂
IV
6400 A₃ 40 80 6520 A₄ 60 6600 40 80 6720 B₁ B₂ 60 6800 40 B₃
SrF₂
V
B₃ C₁ C₂ C₃ C₄
4880 C₁ 4920 60 5000 C₂ 40 80 C₃ 5120 60
BaF₂
VI
B₁ B₂ C₁ B₃

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Fig. IV.—Spectrum of SrF_2 λ 5620–λ 6420. Proceeding towards the red, there are the groups A_3, A_4, B_1, B_2, and B_3, in succession. The dot at about λ 6284 marks the "tail" of the series B_1, and that at about λ 6394 shows the "tail" of the series B_3.

Fig. V.—Spectrum of SrF_2 λ 6380–λ 6870, showing the groups B_3, C_1, C_2, C_3, and C_4, from left to right.

Fig. VI.—Spectrum of BaF_2 λ 4937–λ 5160, showing the group B_1, B_2, C_1, and B_3, in succession from left to right. The dots mark the positions of the tails of the respective series.